

### Legend

#### Fecal Coliform

- < 200 (<1x threshold)
- 200 - 400 (1-2x threshold)
- 400 - 1000 (2-5x threshold)
- >= 1000 (>= 5x threshold)

- Rivers
- Lakes
- Illinois River Watershed

*Notes:*

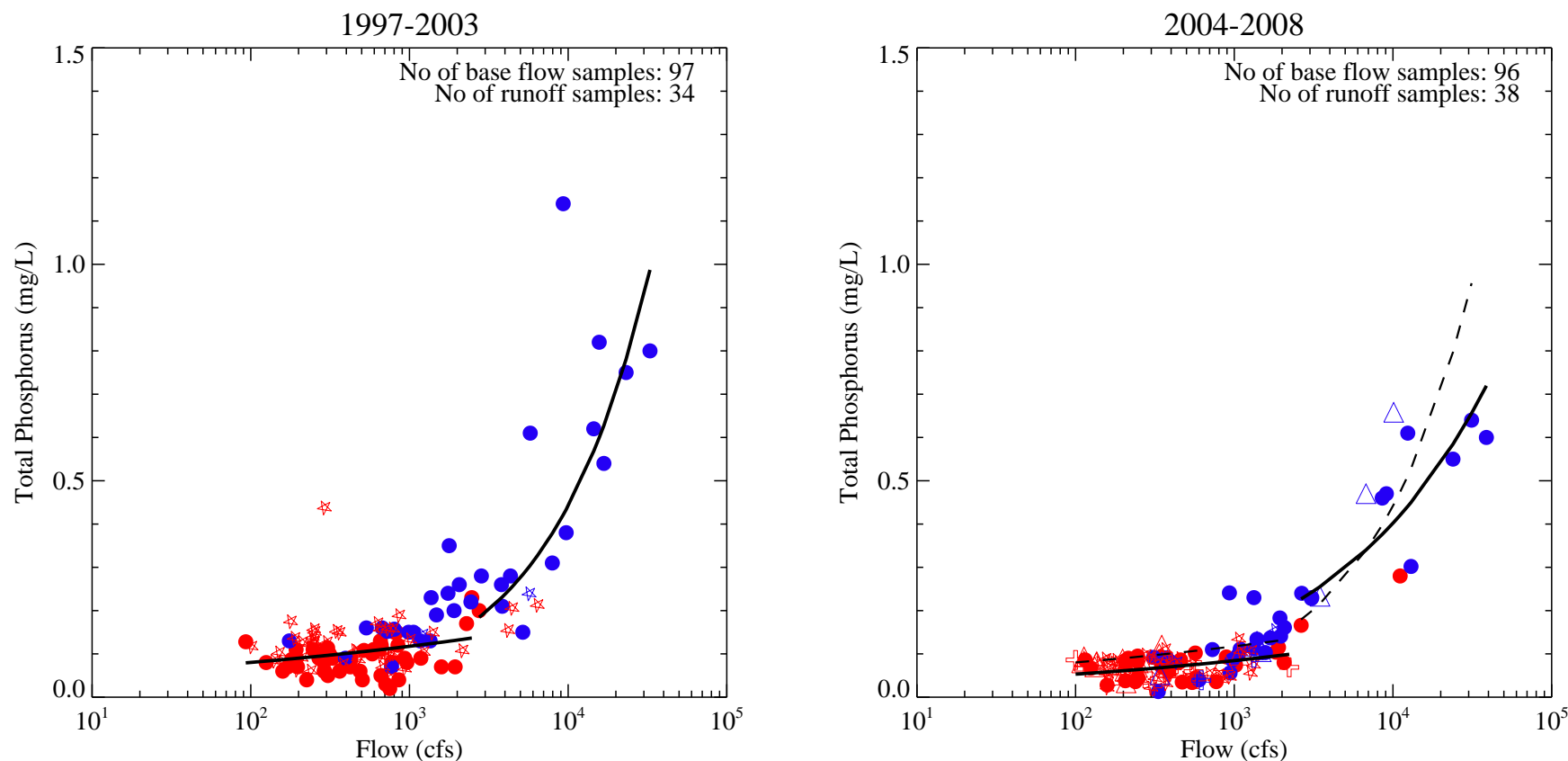
- 1) Data represent the May - September time period.
- 2) Stations with fewer than 5 data records were omitted.
- 3) Samples below the quantitation limit were averaged in at the quantitation limit.
- 4) Units for bacteria are cfu/100 ml or mpn/100 ml.

Data sources may include: Plaintiffs' data collected 2005 - 2007, OKCC, OWRB, USGS and STORET-Modern.

**Figure 6-5i.**  
**2006 Fecal Coliform seasonal  
geometric mean counts at  
sampling locations throughout  
Oklahoma.**

**QEA**  
Quantitative Environmental Analysis, LLC

OICiln:114 January 2009



**Figure 7-1. Total phosphorus concentrations as a function of flow at Tahlequah.**

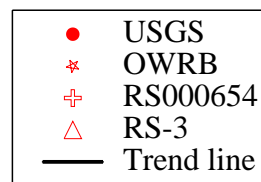
*Red points are base flow conditions, blue points are runoff conditions.*

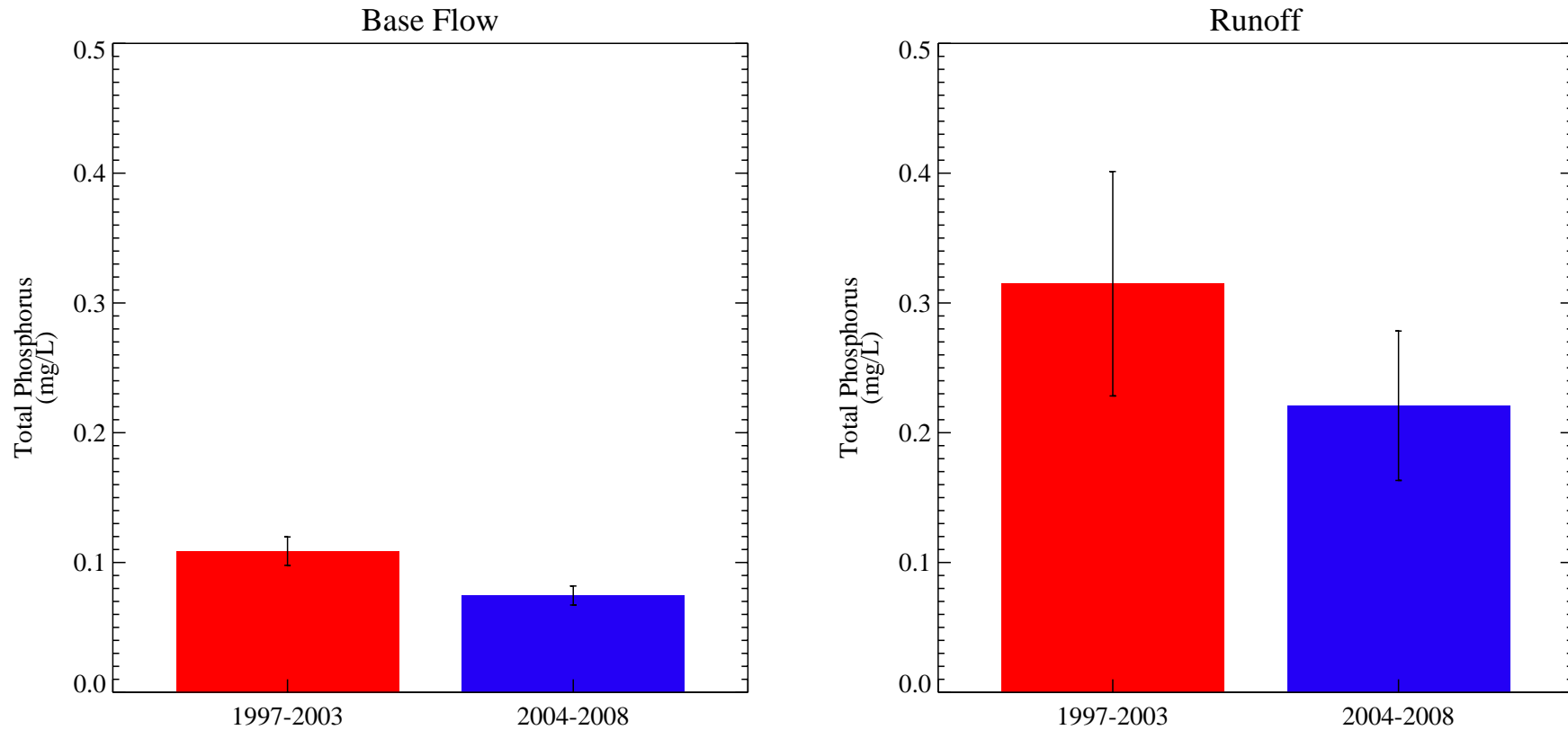
*Regression lines are least square estimates for flows  $\leq 2500$  cfs and flows  $> 2500$  cfs.*

*The dashed line in the second panel represents 1997-2003 trend line for comparison.*

*Base flow conditions are days when base flow is 70% or greater of total flow.*

*Data: USGS 1997 - 2008, Plaintiff's Database 2004-2008, OWRB 1998 - 2008.*

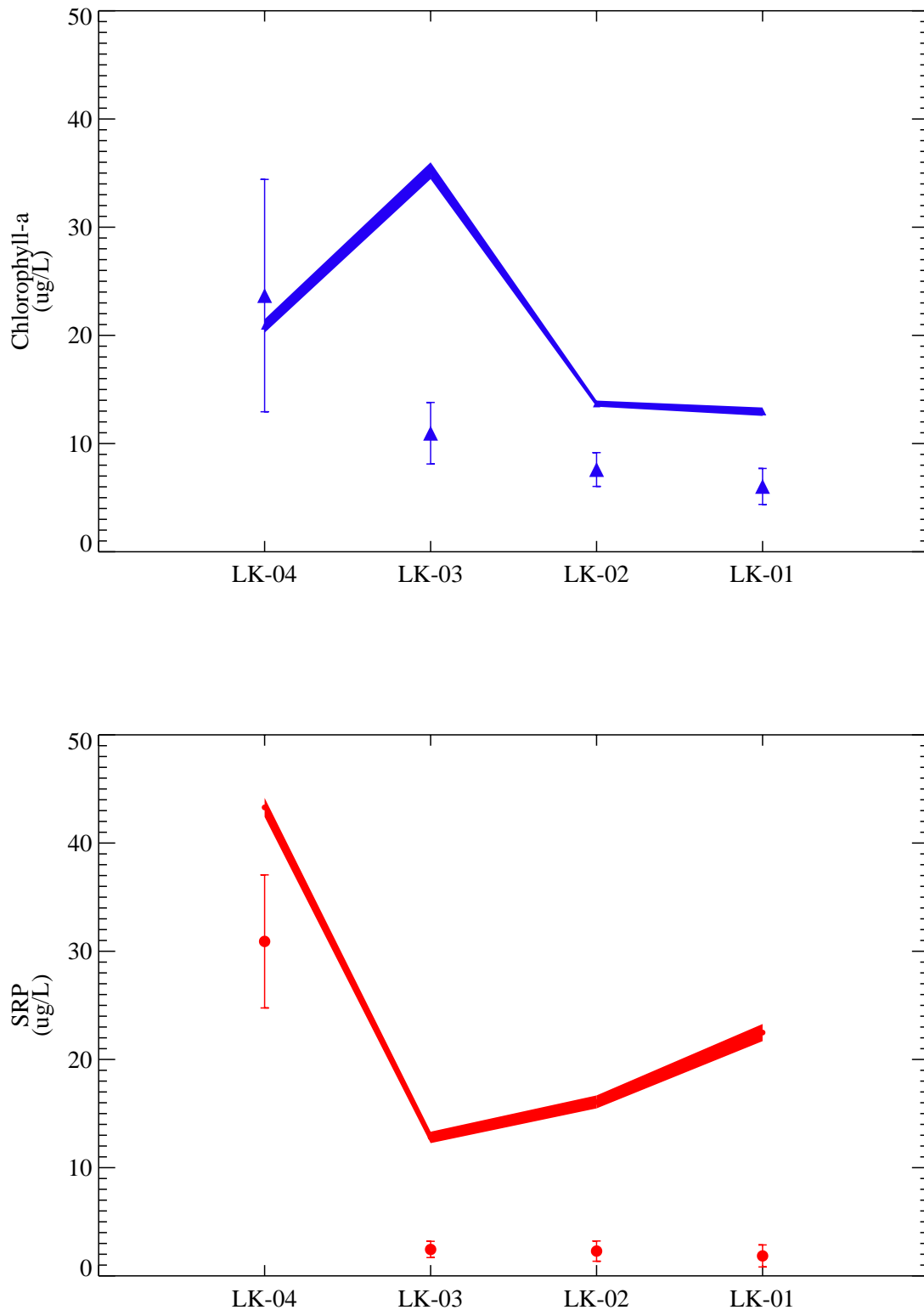




**Figure 7-2. Average total phosphorus during base flow and run off events at Tahlequah.**

*Error bars at +/- 2 standard errors.*

*Data: USGS 1997-2008, Plaintiff's Database 2004-2008, OWRB 1998-2008.*



**Figure 8-1. Average surface SRP and chlorophyll-a concentrations in Lake Tenkiller.**

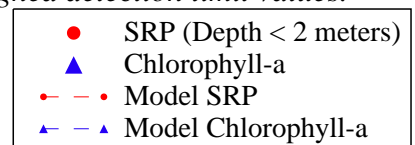
*Error bars and band at +/- 2 Standard Errors. Non detects assigned detection limit values.*

*Data considered for top 2 meters.*

*Only SM18-4500PF method is considered for SRP.*

*Model results are from Dr. Scott Wells' calibration run 400.*

*Data source: Plaintiff's Database 2004-2008.*



**APPENDIX A**  
**Full resume of Dr. John P. Connolly**



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## JOHN P. CONNOLLY, Ph.D., P.E., BCEE

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### CONTACT INFORMATION

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### PROFESSIONAL HISTORY

Quantitative Environmental Analysis, LLC, President and Senior Managing Engineer, February 1998 to present  
 USEPA Science Advisory Board, 2005 to present  
 HydroQual, Inc., Principal Engineer, 1993 to January 1998  
 HydroQual, Inc., Consultant, 1980 to 1993  
 Manhattan College, Professor, 1992 to 1994  
 Manhattan College, Associate Professor, 1986 to 1992  
 Manhattan College, Assistant Professor, 1980 to 1986  
 U.S. Environmental Protection Agency, Environmental Scientist, 1978 to 1980  
 Manhattan College, Research Engineer, 1975 to 1977

### EDUCATION

The University of Texas at Austin, Ph.D., 1980  
 Manhattan College, M.E., Environmental Engineering, 1975  
 Manhattan College, B.E., Civil Engineering, 1973

### REGISTRATION

Professional Engineer, State of Texas (License No. 92122)  
 Professional Engineer, State of New York (License No. 59428)

### EXPERIENCE SUMMARY

Dr. Connolly is a nationally recognized expert on contaminated sediments and eutrophication. His work has been directed to surface water and groundwater contamination problems for the purposes of allocation among potential sources, evaluation of remedial options, remedy design or wasteload allocation (TMDLs). He is expert in water quality modeling and has been involved in the development of several models commonly applied to real world problems. He is also recognized for his ability to communicate complex technical results to the range of stakeholders typically involved in projects and is frequently called on to make presentations at regulatory hearings, community meetings and national and regional technical forums. Dr. Connolly has participated in negotiations with regulatory agencies to craft consent decrees governing contaminated sediment sites.

Dr. Connolly is frequently invited to participate in government and industry sponsored workshops. He is a member of the USEPA Science Advisory Board. He has worked throughout the U.S., in Latin America, and in Europe. He has served as an expert witness for industry and government agencies and has provided testimony before the U.S. Congress and the New York State Assembly. He is also a member of the Manhattan College Council of Engineering Affairs.

### RECENT TESTIMONY

#### **NCR Corporation vs. AIG Centennial Insurance Co. et al. – State of Wisconsin Circuit Court Brown County**

For plaintiff NCR Corporations; expert witness testimony at deposition on 12/27/08 regarding whether PCB released up to the early 1970s continued to cause damage to the Lower Fox River and its biota during the insured period.

#### **Town of Oyster Bay vs. Northrop Grumman Systems Corp., United States Navy and United States of America – United States District Court, Eastern District of New York**

For defendants United States Navy and United States of America; expert witness testimony at deposition on 6/27/07 regarding the likelihood that PCBs in the soils of a town park originated from a site on Grumman property owned by the United States Navy.

**Maine Environmental Protection Board.**

Expert testimony given on 5/2/07 regarding the deficiencies of a phosphorus, TSS and BOD TMDL developed for Gulf Island Pond on the Androscoggin River and the contributions of various sources to existing algal and dissolved oxygen problems.

**Subcommittee on Water Resources and Environment of the U.S. House of Representatives Transportation and Infrastructure Committee Hearing on Strategies to Address Contaminated Sediments.**

Expert testimony given on 7/19/01 regarding the approaches used by USEPA to address contaminated sediments.

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**MAJOR PROJECTS****Contaminated Sediments Assessment and Management****Peer Review of Contaminated Sediment Remediation Guidance for Hazardous Waste Sites**

*Client: USEPA*

One of three national experts tasked with reviewing the draft guidance document which has been developed to provide technical and policy guidance to project managers and management teams making remedy decisions for contaminated sediment sites.

**Source Allocation for Mercury in the Penobscot River Estuary**

*Client: Mallinckrodt, Inc.*

Principal investigator for evaluation of the relative contributions of sediment and water column mercury to mercury found in resident biota. This study involved data analysis and development of a conceptual modeling explaining the probable reasons of the apparent lack of impact of elevated sediment mercury concentrations on biota mercury levels. The work was used to provide litigation support through expert testimony. Subsequent to litigation, work has focused on development of a detailed investigation plan, interaction with a court-mandated Study Panel, technical support for the client's legal team and oversight of planned field work.

**Source Allocation for Mercury in the Peconic River**

*Client: Brookhaven National Laboratory*

Principal investigator for investigations to determine the sources of methyl mercury in the fish of the Peconic River. This study involved the design of sampling programs and interpretation of data to determine the relative contributions of background sources and various sediment deposits throughout the river to methyl mercury in the water and fish. This work was conducted to satisfy a diverse group of stakeholders with differing positions on appropriate remediation. It led to a revision of the contemplated remedial action and a convergence of opinion on the best approach for the river.

**Investigation of Mercury in Lavaca Bay**

*Client: Alcoa*

Principal investigator for the evaluation of mercury sources and prediction of the impacts of remedial actions and storm events on mercury levels in sediment and biota. The project involves data analysis and the development of linked hydrodynamic, sediment transport, mercury fate and bioaccumulation models. A primary goal is the evaluation of the impact of hurricanes and other rare storms on buried mercury.

**Remediation of the Hudson River PCBs Site**

*Client: General Electric Company*

Principal investigator for various aspects of remedial design (RD), including the design and execution of an extensive pre-design sediment sampling program involving the collection of more than six thousand sediment cores, management of the RD database, determination of the dredging prisms, design and execution of the baseline and construction monitoring programs and support of the design of dredging and processing of dredged sediment. This project included the development of sophisticated data entry, data processing and data display systems that were used by the GE design team. Additional activities included direct participation in consent decree negotiations.

**Analysis of the Fate of PCBs in the Hudson River**

*Client: General Electric Company*

Principal investigator for extensive data analysis and modeling studies of the dynamics of PCBs in the Hudson River. This study involved field sampling, data analysis and the development of linked hydrodynamic, physical/chemical, sediment transport and food chain models for the purpose of predicting the effects of alternative remediation plans.

**Analysis of the Fate of PCBs in the Grasse River***Client: Alcoa*

Principal investigator for the determination of the impacts of contaminated sediments and point sources to PCB contamination in resident fish. Efforts include the design of field sampling programs, estimation of PCB fluxes between water and sediment, including the importance of areas of elevated concentrations and the transport and bioaccumulation in the food web. Goal is to provide a technical basis for examination of remedial options.

**Assessment of Contribution of PCBs to the Kalamazoo River from Eaton Corporation***Client: Eaton Corporation*

Principal investigator for the analysis of data and development of models to evaluate whether either or both of two Eaton facilities contributed measurable quantities of PCBs to the Kalamazoo River. The project involved the compilation and analysis of historical data, design and execution of a sampling program and the development of models to predict the transport of sediment and PCBs through the Kalamazoo River.

**Analysis of the Fate of PCBs in the Housatonic River***Client: General Electric Company*

Technical advisor for extensive data analysis and modeling studies directed to determining the appropriate remedial solution for the contaminated sediments. This study involves data analysis and the development of linked hydrodynamic, sediment transport, PCB fate and PCB bioaccumulation models. An important aspect of this project is the evaluation of the role of river flooding in PCB fate and impact of flood plain soils.

**Modeling of Heavy Metal and Organic Contaminant Fate in the Pawtuxet River to Support a RCRA Facility Investigation***Client: Ciba-Geigy Corporation*

Principal investigator for determination of target chemicals by qualitative risk analysis, design of a sampling program and development of a model to evaluate temporal and spatial concentration reductions resulting from remedial action alternatives including excavation and groundwater treatment.

**Analysis of DDE and PCB Transfer Pathways in the Southern California Bight Ecosystem***Client: National Oceanic and Atmospheric Administration*

Principal investigator for the analysis of data and development of food chain models to study the relationship between sediment contamination and levels of DDE and PCBs in fish, mammals, and birds. The purpose of this work was to establish probable sources of contamination in support of a Natural Resource Damages Assessment.

**Contaminated Groundwater Assessment and Management****Evaluation of Solvent Plume Migration and Fate at the MW Manufacturing Site, Valley Township of Pennsylvania***Client: Lucent Technologies*

Principal investigator for the development and application of flow and transport models to be used to predict the movement and decay of a VOC plume composed of PCE, TCE, 1,2-DCE and vinyl chloride. The goal of the project is to estimate whether the plume has achieved a steady-state configuration in response to a non-aqueous phase source and to project discharge rates to a local stream.

**Modeling of Groundwater Remediation Using Vertical Groundwater Circulation Technology***Client: SBP Technologies*

Principal investigator for the development of a strategy to model the treatment efficiency of *in-situ* vertical groundwater circulation technology. Work included the evaluation of circulation, nutrient dynamics and PAH biodegradation and volatilization. The goal was to develop a modeling framework that could be used to design sampling strategies and evaluate treatment efficiency.

**Total Maximum Daily Load (TMDL) Investigations****Evaluation of the Phosphorus, TSS and BOD TMDL for Gulf Island Pond on the Androscoggin River, Maine***Client: Verso Paper Company*

Principal investigator for the critique of the TMDL developed by Maine DEP and the examination of the contributions of point and non-point sources to algal and dissolved oxygen problems in the Pond.

**San Francisco Bay PCBs***Client: General Electric Company*

Principal investigator for the review and critique of a draft TMDL document issued by the San Francisco Bay Regional Water Quality Control Board. This study involved the analysis of data and modeling to provide the Board with the information necessary to correct deficiencies in the draft document with regard to natural recovery



and the need for, and effectiveness of, available source control options and to develop an effective implementation strategy. It included the development of presentation materials and a face-to-face meeting with the authors of the document.

#### **Coosa River PCBs**

*Client: General Electric Company*

Principal investigator for the review and critique of a draft TMDL document issued by the State of Georgia. This study involved the analysis of data to provide the State with the information necessary to correct deficiencies in the draft document with regard to natural recovery and the need for, and effectiveness of, available source control options and to develop an effective implementation strategy. It included the development of presentation materials and a face-to-face meeting with the State and with EPA Region 4.

#### **Water Quality/Eutrophication Assessment**

##### **Assessment of the Environmental Fate and Impact of ICE-B-GON on Lake Wingra, Wisconsin**

*Client: Chevron Research Company*

Principal investigator for the laboratory determination of the degradation and oxygen utilization kinetics of the de-icing chemical, ICE-B-GON and projection of the effect of the use of this chemical on the dissolved oxygen of receiving waters using Lake Wingra as a case study.

##### **Mathematical Modeling of Water Quality in Lake Erie**

*Client: U.S. Environmental Protection Agency, Grosse Ile, Michigan*

Project Engineer in charge of data analysis development and calibration of an eutrophication model including multiple algal species and zooplankton, and projections of the effects of reduction in point and non-point nutrient loadings on pollution indicators; lake phytoplankton, nutrient, and dissolved oxygen levels.

##### **Analysis of Heavy Metals, Ammonia and Cyanide in the Genesee River**

*Client: Eastman Kodak Corporation*

Project Engineer in charge of data analysis, mathematical model development and assessment of the relative impact of the Kodak treatment plant effluent on water quality in the River.

##### **Analysis of the Fate of Toxic Chemicals in Estuaries**

*Client: U.S. Environmental Protection Agency, Gulf Breeze, Florida*

Project Manager in charge of development of a mathematical model describing the transport and degradation of toxic chemicals in estuarine environments.

##### **Development of Version 4.0 of the Water Analysis Simulation Program (WASP)**

*Client: U.S. Environmental Research Laboratory, Athens, Georgia*

The purpose of this project was to modify the USEPA water quality model WASP (3.2) to provide a single modeling framework for use in all types of surface water problems including conventional and toxic pollutants under steady-state or time-variable conditions. Responsibilities included the development of the kinetic routines for the toxic chemical component of the model from those used in EXAMS II, TOXIWASP and WASTOX, integration of the WASTOX steady-state solution into WASP and providing technical assistance on all other components of model development.

#### **Ecological Risk/Natural Resource Damage Assessments**

##### **Development of Water Quality Criteria for Wildlife**

*Client: U. S. Environmental Protection Agency*

Principal investigator for the development of methodologies to determine water concentrations protective of aquatic feeding wildlife. Defined methods to relate laboratory toxicity estimates to wildlife species. Efforts included compilation and analysis of toxicity data, development of models to permit extrapolation of laboratory toxicity data to field animals and development of models of the relationship between water column contaminant concentrations and effects in wildlife. Initial work focused on dieldrin and DDT.

##### **Modeling PCBs in the Aquatic Biota of Green Bay**

*Client: U.S. Environmental Protection Agency*

Principal investigator for the development and application of a model of PCBs in the food web of Green Bay. This work is part of the Green Bay Mass Balance Study for the U.S. Environmental Protection Agency. The purpose of these studies was to evaluate the impacts of potential remediation alternatives.

**Analysis of PCBs and Metals Contamination in the Biota of New Bedford Harbor, Massachusetts***Client: U.S. Environmental Protection Agency, Region I, Battelle Ocean Sciences*

Project manager in charge of developing a mathematical model of the contamination of the lobster and winter flounder and their food chains in New Bedford Harbor and Buzzards Bay. Responsible for linking this model with a hydrodynamic-contaminant fate model developed by Battelle Northwest to project the response of the biota to various remedial action alternatives. This work was part of an EPA Superfund project in New Bedford Harbor.

**Analysis of PCBs in the Hudson River Striped Bass and its Food Chain***Client: Hudson River Foundation, New York, NY*

Project manager in charge of the development of a mathematical model describing the accumulation of PCBs in the striped bass food chain.

**Analysis of Kepone Accumulation in the Striped Bass Food Web of the James River Estuary***Client: U.S. Environmental Protection Agency, Gulf Breeze, Florida*

Project manager in charge of the development and application of a mathematical model describing the accumulation of the pesticide Kepone in the striped bass food chain. Projected the response of the food chain to declining exposure concentrations.

**Pathogen Fate and Transport****Development of a Framework for Predicting the Fate of Genetically Engineered Microorganisms in Surface Water Systems***Client: U.S. Environmental Protection Agency, Environmental Research Laboratory, Gulf Breeze, Florida*

Principal investigator for the development of a model of the population dynamics of bacteria, phytoplankton and zooplankton in surface waters and application of this model to predicting the risk associated with the introduction of genetically engineered bacteria to these environments. Population dynamics models were developed for the Delaware River and Mirror Lake.

**Modeling Fate and Transport of Pathogenic Organisms in Mamala Bay, Hawaii***Client: Mamala Bay Study Commission*

Principal investigator for review of historical data, design of a sampling program and development and calibration of a mathematical model of pathogen fate in Mamala Bay. Goal is to determine pathogen sources and level of control necessary to meet water quality goals.

**Evaluation of Cryptosporidium Sources and Fate in Milwaukee, Wisconsin***Client: Sara Lee Corporation*

Principal investigator for the evaluation of the likely contribution of various potential sources to the Cryptosporidium responsible for a disease outbreak in the city of Milwaukee.

**Hydraulic Engineering****Hydraulic Analysis of the Fairfield, New Jersey Sewer System***Client: Lee Purcell Associates, Inc.*

Project engineer in charge of determining the capacity and flow characteristics of an in-place sewer system. Developed a gradually varied flow analysis for this purpose.

**HONORS**

Diplomate Environmental Engineer by Eminence, American Academy of Environmental Engineers, 2002  
Manhattan College Environmental Engineering Alumni Club Service Award, 1994

**PROFESSIONAL ACTIVITIES****Affiliations**

American Academy of Environmental Engineers  
Sigma Xi - The National Scientific Research Society  
Society of Environmental Toxicology and Chemistry  
American Society of Limnology and Oceanography  
Water Environment Federation

**Committees and Advisory Boards**

2005	USEPA Science Advisory Board
1997	USEPA Technical Qualifications Board to review promotion application
1991-96	New York Water Environment Association Outstanding Paper Award Committee
1990-95	DuPont Technical Advisory Board for Evaluation of HMPA Releases at their Spurance Plant in Richmond, VA
1990	USEPA Exploratory Research Review Panel

**Invited Participation in Technical Workshops**

**Addressing Uncertainty and Managing Risk at Contaminated Sediment Sites.** St. Louis, MO October 26-28, 2004 – Steering Committee Member.

**SERDP/ESTCP Contaminated Sediments Workshop.** Arlington, VA August 10-11, 2004.

**Stability of Chemicals in Sediments.** San Diego, CA April 8-10, 2003 – Steering Committee Member.

**Sediment Stability Workshop.** New Orleans, LA, January 22-24, 2002 – Steering Committee Member.

**U.S. EPA Forum on Contaminated Sediments.** Alexandria, VA, May 30-June 1, 2001.

**National Research Council Workshop on Bioavailability.** Washington, D.C., November 12, 1998.

**SETAC Pellston Workshop: Re-evaluation of the State of the Science for Water Quality Criteria Development.** Fairmont Hot Springs, MT, June 25-30, 1998.

**National Academy of Sciences National Symposium on Contaminated Sediments.** Washington, D.C., May 27-29, 1998.

**SETAC Pellston Workshop: Reassessment of Metals Criteria for Aquatic Life Protection.** Pensacola, FL, February 10-14, 1996.

**California EPA Workshop on Critical Issues in Assessing Ecological Risk.** Asilomar, CA, January 23-25, 1995.

**USEPA Workshop on Taura Syndrome.** Gulf Breeze, FL, August 2-3, 1994.

**USEPA Workshop on Modeling Uncertainty.** Buffalo, NY, February 3-5, 1991.

**USEPA Workshop on Sediment Quality Criteria.** Grosse Ile, MI, March 29-30, 1990.

**Industry Sponsored Workshop on the Environmental Impacts of the Deicer Calcium-Magnesium-Acetate.** Albany, NY, February 27, 1990.

**USEPA Workshop on Biotechnology Risk Assessment.** Breckenridge, CO, January 11-15, 1988.

**SETAC Workshop on Risk Assessment.** Breckenridge, CO, August 17-21, 1987.

**PRESENTATIONS**

**Overview of the 2005 Grasse River Remedial Options Pilot Study.** Fourth International Conference on Remediation of Contaminated Sediments, Savannah, GA, January 22-25, 2007.

**Challenges to Monitoring and Assessing Natural Recovery.** Third International Conference on Remediation of Contaminated Sediments, New Orleans, LA, January 27, 2005.

**Monitoring to Support the Dredging Remedy on the Upper Hudson River.** Third International Conference on Remediation of Contaminated Sediments, New Orleans, LA, January 26, 2005.

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- Adaptive Management as a Measured Response to the Uncertainty Problem.** Addressing Uncertainty and Managing Risk at Contaminated Sediment Sites, St. Louis, MO, October 27, 2004
- Optimal Use of Conceptual and Mathematical Models at Contaminated Sediment Sites.** Addressing Uncertainty and Managing Risk at Contaminated Sediment Sites, St. Louis, MO, October 27, 2004
- Sampling of Sediment and Water in the Upper Hudson River to Support the USEPA Dredging Remedy.** Hudson River Environmental Society Conference, RPI, Troy, NY, October 5, 2004
- Nature and Causes of Non-Particle Related Contaminant Releases in Large River Systems.** Workshop on Environmental Stability of Chemicals in Sediments, San Diego, CA, April 10, 2003
- Management of Contaminated Sediments.** NSF US/Italy Workshop on Sediments, Arlington, VA, December 10, 2002
- Use of Sound Science to Develop a Defensible Site Model.** U.S. EPA Forum on Managing Contaminated Sediments, Alexandria, VA, May 31, 2001.
- A Quantitative Framework for Evaluating Contaminated Sediment Sites.** SETAC 20<sup>th</sup> Annual Meeting, Philadelphia, PA, November 14-18, 1999.
- Prediction of Natural Recovery and the Impacts of Active Remediation in the Upper Hudson River.** SETAC 20<sup>th</sup> Annual Meeting, Philadelphia, PA, November 14-18, 1999.
- Evaluation of Remedial Alternatives for Contaminated Sediments: A Coherent Decision-Making Approach.** National Research Council, National Symposium on Contaminated Sediments, Washington, D.C., May 28, 1998.
- Applications of Models to the Risk Assessment Problem.** Chesapeake Biological Laboratory, Solomans, MD, November 1, 1996.
- Use of Food Web Models to Evaluate Bioaccumulation Data.** National Sediment Bioaccumulation Conference, Bethesda, MD, September 11, 1996.
- Assessment and Remediation of Contaminated Sediments at MGP Sites.** Electric Power Research Institute, Monterey, CA, August 28, 1996.
- Modeling the Environmental Fate and Transport of Metals.** 26th Pellston Workshop: Reassessment of Metals Criteria for Aquatic Life Protection, Pensacola, FL, February 11, 1996.
- Toxicologically Based Ecological Risk Assessment.** California EPA Workshop on Critical Issues in Assessing Ecological Risk, Asilomar, CA, January 24, 1995.
- Data Requirements for the Development and Use of Water Quality Models.** USEPA Conference on Quality Assurance in Environmental Decision Making, IBM T.J. Watson Research Center, Yorktown Heights, NY, November 2, 1994.
- Mathematical Modeling of the Bioaccumulation of Hydrophobic Organics.** National Biological Survey, Columbia, MO, August 25, 1994.
- A Model-Based Evaluation of PCB Bioaccumulation in Green Bay Walleye and Brown Trout.** International Association for Great Lakes Research 36th Conference on Great Lakes Research, De Pere, WI, June 7, 1993.
- Bioaccumulation Modeling of Micropollutants in the Field.** International Workshop on Mechanisms of Uptake and Accumulation of Micropollutants, Veldhoven, The Netherlands, May 25, 1993.
- Keynote Presentation.** NIEHS Sponsored Workshop on the Bioaccumulation of Hydrophobic Organic Chemicals in Aquatic Organisms, June 29, 1992.
- Modeling the Role of Bacteria in Carbon Cycling.** Gordon Research Conference, New Hampton, New Hampshire, June 17, 1992.
- Calcium Magnesium Acetate Biodegradation and its Impact on Surface Waters.** Symposium on the Environmental Impact of Highway Deicing, University of California, Davis, October 13, 1989.

**Food Chain Modeling in the Green Bay Mass Balance Study.** International Association for Great Lakes Research 32nd Conference on Great Lakes Research, Madison, WI, June 2, 1989.

**Modeling the Fate of Bacteria in Aquatic Systems.** American Society for Microbiology Annual Conference, New Orleans, LA, May 18, 1989.

**Application of a Food Chain Model to Evaluate Remedial Alternatives for PCB-Contaminated Sediments in New Bedford Harbor, MA,** Superfund '88, Washington, D.C., November 29, 1988.

**Modeling the Accumulation of Organic Chemicals in Aquatic Animals.** Joint USA/USSR Symposium: Fate of Pesticides and Chemicals in the Environment, The University of Iowa, Iowa City, IA, November 15, 1987.

**Modeling Kepone in the Striped Bass Food Chain of the James River.** Virginia State Water Control Board, Richmond, VA, August 15, 1983.

**Predicting the Effects of Toxic Chemicals in Natural Water Systems.** U.S. Environmental Protection Agency, Environmental Research Lab, Athens, GA, November 3, 1982.

**Modeling Toxic Substances in Aquatic Food Chains.** Clarkson College Environmental Engineering Graduate Program, Potsdam, NY, October 29, 1982.

**Predicting the Effects of Toxic Chemicals in Natural Water Systems.** U.S. Environmental Protection Agency, Environmental Research Lab, Gulf Breeze, FL, September 13, 1982.

**Modeling of Fate of Toxic Chemicals in Aquatic Systems.** U.S. Environmental Protection Agency, Office of Toxic Substances, Washington, D.C., March 16, 1982.

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## PUBLICATIONS

**Comment on "The Long-Term Fate of Polychlorinated Biphenyls in San Francisco Bay, (USA)".** Connolly, J.P., C.K. Ziegler, E.M. Lamoureux, J.A. Benaman and D. Opydke, *Environ. Toxicol. Chem.* 24:2397-2398, 2005.

**p,p'-DDE Bioaccumulation in Female Sea Lions of the California Channel Islands.** Connolly, J.P. and D. Glaser, *Continental Shelf Res.* 22:1059-1078, 2002.

**A model of p,p'-DDE and total PCB bioaccumulation in birds from the Southern California Bight.** Glaser D, J.P. Connolly, *Continental Shelf Research* 22:1079-1100, 2002.

**Use of a Bioaccumulation Model of p,p'DDE and Total PCB in Birds as a Diagnostic Tool for Pathway Determination in Natural Resource Damage Assessments.** Glaser, D. and J.P. Connolly, *Continental Shelf Res.* In press.

**Modeling of Flood and Long-Term Sediment Transport Dynamics in Thompson Island Pool, Upper Hudson River.** Ziegler, C.K., P. Israelsson and J.P. Connolly, *Water Quality and Ecosystem Modeling* 1:193-222, 2000.

**Modeling of Natural Remediation: Contaminant Fate and Transport.** Peyton, B.M., T.P. Clement and J.P. Connolly, In: *Natural Remediation of Environmental Contaminants: Its Role in Ecological Risk Assessment and Risk Management*, Swindoll, C.M., R.G. Stahl & S.J. Ells, eds., SETAC Press, 472 p., 2000.

**The Use of Ecotoxicology and Population Models in Natural Remediation.** D. Glaser and J.P. Connolly, In: *Natural Remediation of Environmental Contaminants: Its Role in Ecological Risk Assessment and Risk Management*, Swindoll, C.M., R.G. Stahl & S.J. Ells, eds., SETAC Press, 472 p., 2000.

**A Model of PCB Fate in the Upper Hudson River.** Connolly, J.P., H.A. Zahakos, J. Benaman, C.K. Ziegler, J.R. Rhea and K. Russell, *Environ. Sci. Technol.* 34:4076-4087, 2000.

**Modeling the Fate of Pathogenic Organisms in the Coastal Waters of Oahu, Hawaii.** Connolly, J.P., A.F. Blumberg and J.D. Quadrini, *J. Environ. Eng.* 125:398-406, 1999.

**Bacteria and Heterotrophic Microflagellate Production in the Santa Rosa Sound, FL.** Coffin, R.B. and J.P. Connolly, *Hydrobiologia* 353:53-61, 1997.



- Hudson River PCBs: A 1990s Perspective.** Rhea, J., J. Connolly and J. Haggard, *Clearwaters*, 27:24-28, 1997.
- Modeling the Environmental Fate and Transport of Metals.** Connolly, J.P., In: *Reassessment of Metals Criteria for Aquatic Life Protection*, Bergman H.L. and E.J. Dorward-King, eds., SETAC Press, 1997.
- The Use of Vertical Groundwater Circulation Technology: A Preliminary Analysis of the Fate and Transport of Polycyclic Aromatic Hydrocarbons in a Shallow Aquifer.** Connolly, J.P. and J.D. Quadri, In: *In Situ Bioremediation and Efficacy Monitoring*, Spargo, B.J. ed., Naval Research Laboratory, NRL/PU/6115-96-317, 1996.
- A Model of Carbon Cycling in the Planktonic Food Web.** Connolly, J.P. and R.B. Coffin, *J. Envir. Eng.* 121:682-690, 1995.
- The Impact of Sediment Transport Processes on the Fate of Hydrophobic Organic Chemicals in Surface Water Systems.** Ziegler, C.K. and J.P. Connolly, *Toxic Substances in Water Environments: Assessment and Control*, Proceedings of the Water Environment Federation Specialty Conference, May 14-17, 1995.
- Uncertainty in Bioaccumulation Modeling.** Glaser, D. and J.P. Connolly, *Toxic Substances in Water Environments: Assessment and Control*, Proceedings of the Water Environment Federation Specialty Conference, May 14-17, 1995.
- Toxicologically Based Ecological Risk Assessment.** Connolly, J.P., In: *Critical Issues in Assessing Ecological Risk*, Summary of Workshop held at Asilomar Conference Center, Pacific Grove, CA, University Extension, University of California, Davis, January 23-25, 1995.
- Availability of Dissolved Organic Carbon to Bacterioplankton Examined by Oxygen Utilization.** Coffin, R.B., J.P. Connolly and P.S. Harris, *Mar. Ecol. Prog. Ser.* 101:9-22, 1993.
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## **APPENDIX B**

### **Trace Elements in the Environment**

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## **APPENDIX B**

### **TRACE ELEMENTS IN THE ENVIRONMENT**

As discussed in Section 2.4 of this report, the plaintiffs' consultants Drs. J. Berton Fisher and Roger Olsen used trace elements present in poultry litter to estimate the contribution of poultry litter to phosphorus in the Illinois River Watershed and Lake Tenkiller. However, the elements used are poor tracers. As presented in Section 2.4, the relative proportions of phosphorus (P) to zinc (Zn), copper (Cu), and arsenic (As) vary among the different media sampled by Dr. Olsen in the Illinois River Watershed. This is expected given the differing properties of the media and the different leaching rates and fate and transport properties of these chemicals. Additionally, the multiple sources of these chemicals further confound their use as tracers of a source material.

P, Zn, Cu, and As have differing chemical properties. P is a highly reactive, relatively insoluble non-metal that is one of the key elements required for life (Brady 1974). Zn and Cu are transition metals essential for plant and animal metabolism. However, Zn only has one significant oxidation state ( $\text{Zn}^{2+}$ ) and is more soluble than copper. Copper can occur in solution as either  $\text{Cu}^{2+}$  or  $\text{Cu}^{1+}$  and readily complexes with many different ligands. Arsenic is a metalloid element that can be present in several oxidation states and thus has fairly complex chemistry (Hem 1985).

As described in Section 2.3 of this report, the divergent transport pathways these chemicals take once leached from poultry litter depends not just on their properties but on the pH, organic matter content, and other properties of the soil to which the poultry litter was applied (Arias et al. 2005). Arsenic is more mobile than zinc and copper (Gupta and Charles 1999). Zinc is more soluble than copper, but copper has a high affinity for dissolved organic matter (DOM) and thus has been shown to be transported farther with high concentrations of DOM (Impellitteri et al. 2002). Phosphorus, particularly in phosphate form, will adsorb to calcium-, iron-, or aluminum-containing soil particles. As these particles are transported from the watershed soils to sediments, some phosphorus forms will continually exchange into the water column, depending upon water column concentrations, and become available for biological

consumption. While this is also true of copper and zinc, the rate and extent that they exchange between soil particles and the water column is quite different, given the higher solubility of zinc, and the relative mobility of copper due to its affinity for DOM. The water chemistry of arsenate, the dominant form of dissolved arsenic in oxidized surface waters, is similar to that of phosphate (Faust and Aly 1981). However, arsenic differs from phosphorus in that it is a redox sensitive element [typically found as As(III) or As(V)] and it is not essential element for biological growth, and thus its fate and transport is expected to diverge from that of phosphorus moving from watershed soils to lake sediments (Hinkle and Polette 1999; Mucci et al. 2000; Linge and Oldham 2004)

The average and range of Cu, Zn, As, and P concentrations in (litter-applied land) LAL soils, Illinois River Watershed stream and lake sediments, Illinois River Watershed control soils, and stream sediments within the Ozarks Plateaus collected through the National Water Quality Assessment Program (NAWQA; Petersen et al. 1998) are provided in are provided in Table A-1. Mean and maximum values in LAL soils, Illinois River Watershed stream and lake sediments are generally higher than those in Illinois River Watershed control soils. As discussed in Section 2.7 of this report, the variability in soil and sediment phosphorus concentrations are controlled in part by the soil and sediment aluminum and iron content. Control soils had lower concentrations of iron and aluminum. Thus, the lower concentrations in control soils may be due in part to soil type and the limited range of sediment types represented due to small sample size. The Ozarks Plateaus Study included the collection of sediments from fourteen locations that represent the range of sediment types, land uses and basin sizes within the Study Unit, which includes the Illinois and six other river basins. As shown on Table A-1, the concentrations of phosphorus, zinc, iron, and arsenic in Illinois River Watershed soils and sediments fall within the range of these values measured within the Ozarks Plateaus. Given that these sediments were collected from a variety of land uses and sediment types, the range in concentrations are likely the result of various sources as well as differences in sediment type. This variability in ambient concentrations confounds the use of these elements as tracers of poultry litter.

**Table B-1. Mean and range of P, Cu, Zn, and As in Illinois River Watershed soils, stream and lake sediments, control soils, and Ozarks Plateaus Study Unit.**

		<b>Number of Observations</b>	<b>Mean</b>	<b>Minimum</b>	<b>Maximum</b>
<b>Total Phosphorus (mg/kg)</b>	Lake sediment	45	1019.3	119.5	2021.6
	Stream sediment	24	543.5	152.3	1776.3
	Litter-applied land soil	166	847.9	46.9	2116.1
	Control soil	15	233.0	86.7	449.9
	Ozarks Plateaus sediment	37	668.4	400.0	1400.0
<b>Total Copper (mg/kg)</b>	Lake sediment	51	12.4	1.3	25.3
	Stream sediment	24	18.5	1.3	248.8
	Litter-applied land soil	166	20.8	3.1	44.9
	Control soil	16	5.7	2.0	13.7
	Ozarks Plateaus sediment	37	20.4	9.0	66.0
<b>Total Zinc (mg/kg)</b>	Lake sediment	51	60.6	10.7	116.9
	Stream sediment	24	58.0	16.0	120.7
	Litter-applied land soil	166	35.0	8.6	130.1
	Control soil	16	21.5	12.2	35.5
	Ozarks Plateaus sediment	37.0	296.0	43.0	5600.0
<b>Total Arsenic (mg/kg)</b>	Lake sediment	51	7.1	1.6	13.7
	Stream sediment	24	5.2	1.3	12.8
	Litter-applied land soil	166	3.4	1.3	8.0
	Control soil	16	2.4	1.4	4.0
	Ozarks Plateaus sediment	37	7.5	2.9	26.0

*Data sources: Plaintiff database, 11/21/08; Ozarks Plateaus Study Unit, USGS National Water Quality Assessment Program Data Warehouse Export, 07/16/2008 (Peterson et al. 1998).*

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## **APPENDIX C**

### **Base Flow 7 UW`Ujcbg**

## APPENDIX C BASE FLOW CALCULATIONS

The base flow separation model used here is derived from Eckhardt's (2005) recursive digital filter separation method. The use of digital filters for baseflow separation has been commonly applied in watershed analyses (Arnold et al. 1995; Arnold and Allen 1999) Because runoff causes high frequency variability of streamflow, low-pass filtering of the hydrograph can be used to identify base flow.

The total flow  $y$  at any time step  $k$  can be divided into base flow and runoff as:

$$y_k = b_k + f_k \quad (1)$$

where:

$$\begin{aligned} f &= \text{runoff; and} \\ b &= \text{baseflow.} \end{aligned}$$

The general form of the one parameter filter model proposed by Eckhardt is

$$b_k = Ab_{k-1} + By_k \quad (2)$$

The coefficients  $A$  and  $B$  are expressed in terms of the rate of groundwater recession,  $a$ , and the long-term ratio of base flow to total flow,  $R$

$$\begin{aligned} A &= \frac{(1-R)a}{1-aR} \\ B &= \frac{(1-a)R}{1-aR} \end{aligned} \quad (3)$$

The parameter  $a$  defines the change in base flow as flow recesses during dry weather periods:

$$b_k = ab_{k-1} \quad (4)$$

It is calculated from the regression of  $b_k$  and  $b_{k-1}$  during dry weather periods.

For a perennial stream with porous aquifers, Eckhardt recommends a value of  $R$  close to 0.80. Using a value of 0.85, the base flow (red) and total flow (black) hydrograph at Tahlequah is shown in Figure C-1. The results of this analysis applied to the 2004 to 2007 USGS flow record at Talequah indicates that approximately 80% of the days during the summer season (May – September) are base flow days (Figure C-2). A base flow day is defined as a day when at least 70% of the total flow is base flow (Tortorelli and Pickup 2006).



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